

Some living and fossil echinoderms from the Bismarck Archipelago, Papua New Guinea, and two new echinoid species

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Starfish and sea-urchin records of the Bismarck Archipelago, Papua New Guinea, are scattered throughout the literature of the past 160 years. This paper lists the region's valid starfish and sea-urchin species records contained in the literature. In addition, records of 17 species of starfish and sea-urchins from material in the Department of Geology, Australian National University and the East New Britain Historical and Cultural Centre collections are included, with descriptions of two new sea-urchin species, the schizasterid *Schizaster (Paraster) ovatus* sp. nov. and the echinometrid *Heliocidaris robertsi* sp. nov. Some Tertiary echinoids from the region are described for the first time, namely *Stereocidaris* cf. *squamosa* Mortensen 1928 (Lower-Middle Miocene: Manus Island), *Stereocidaris* sp. (Pliocene: east New Britain), *Phyllacanthus* sp. (Pliocene: east New Britain) and *Echinoneus* sp. (Pleistocene-Holocene: Tanga Group, New Ireland).

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KEYWORDS: Asteroidea, Bismarck Archipelago, East Indies, Echinoidea, Extant, Fossil, Papua New Guinea, West Pacific.

INTRODUCTION

The Bismarck Archipelago, northern Papua New Guinea (PNG), encompasses the islands of New Britain, Bougainville, New Ireland and adjacent groups (Tabar, Lihir, Tanga and Feni), St. Matthias Group, the Admiralty Group, including Manus Island, and the surrounding waters of the Bismarck Sea (Fig. 1). It lies along the easternmost boundary of the East Indian Faunal Province. To the east and southeast lies the West Pacific Ocean or Melanesia faunal province (Endean 1957 and A.M. Clark and Rowe 1971, respectively).

Knowledge of the extant starfishes and sea-urchins (Echinodermata: Asteroidea and Echinoidea, respectively) from the Bismarck Archipelago comprises records scattered throughout a diverse literature of the past 160 years. The earliest described asteroid is *Echinaster eridanella* Müller and Troschel 1842 (= *Echinaster luzonicus* Gray 1840) with a type locality in New Ireland. Sladen (1889) and A. Agassiz (1879 1881) described the asteroids and echinoids, respectively, collected during the 1873-76 voyage of *H.M.S. Challenger*. This expedition passed through the Admiralty Group and retrieved two new deep-water echinoids in the Bismarck Sea (the arbaciid

Pygmaeocidaris prionigera (A. Agassiz 1879) and the temnopleurid *Prionoechinus sagittiger* A. Agassiz 1879), at a site between the Admiralty Group and New Guinea. Loriol (1891) described additional asteroids from the archipelago, including *Nardoa finschi* de Loriol 1891 (= *Nardoa tuberculata* Gray 1840) and *Nardoa mollis* de Loriol 1891 (= *Nardoa novaecaledoniae* Perrier 1875), both with type localities in New Britain. Bell (1899) described the non-holothurian echinoderms collected by Arthur Willey during his 1895-97 visit to New Britain and the Loyalty Islands (Willey 1902). H.L. Clark (1925) redescribed several of Willey's Bismarck Archipelago echinoids and erected two new species (the arbaciid *Coelopleurus elegans* (Bell 1899) and the diadematid *Micropyga nigra* H.L. Clark 1925) with type localities in New Britain. H.L. Clark (1946) and A.H. Clark (1954) recorded additional asteroids and echinoids from the archipelago. Struder (1876, 1880) and H.L. Clark (1908) provided descriptions of the extant echinoderm fauna of west New Guinea, a region contiguous with the Bismarck Archipelago.

During the past 20 years echinoderm research in the region has concentrated on the biology of asteroids and comatulid crinoids at Hansa Bay and Madang, on the southern shores of the Bismarck Sea

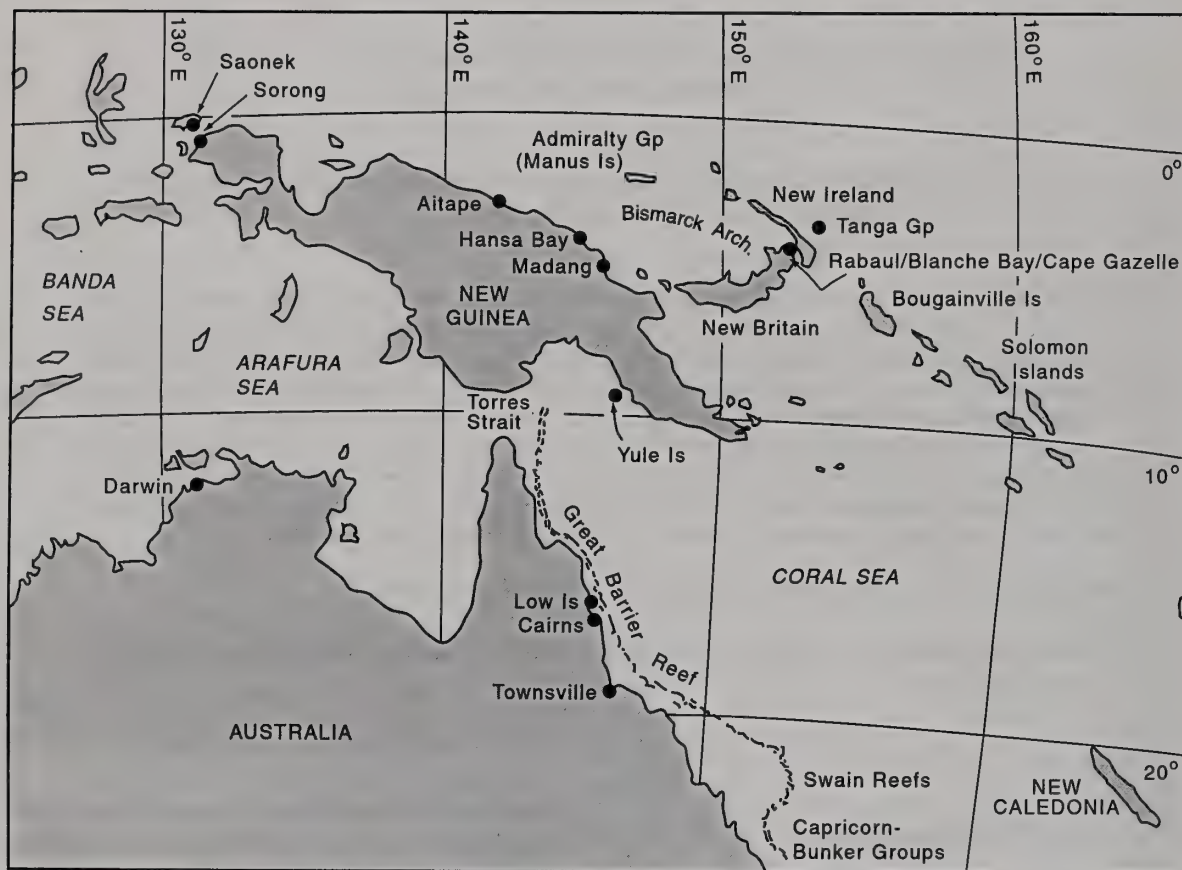


Figure 1. Locality map showing the Bismarck Archipelago, Papua New Guinea, and other localities discussed in text.

(Britayev et al. 1999; Bouillon and Jangoux 1984; Eeckhaut et al. 1996; Messing 1994).

This paper describes some extant asteroids and echinoids from the Bismarck Archipelago. It also provides for the first time, a tabulation of previously reported asteroid and echinoid occurrences (Tables 1 and 2 respectively; tables located after the reference list) in the region. Several Tertiary echinoids from the archipelago are also described. The author is not aware of any previous description of the region's fossil echinoderm fauna.

The specimens described in this paper were collected between 1981-2003, and do not necessarily represent the results of thorough, methodical site collections. The Cape Gazelle, east New Britain,

locality encompasses any one of a number of nearby localities, including Tovarur Plantation, Reiven Beach and southeastern Tokua Airport. Full systematic descriptions are provided for all fossil species while in most cases, only brief remarks concerning the significance of occurrences are provided for extant species. Specimens prefixed ANU are housed in the Department of Geology, The Australian National University; specimens prefixed B are housed in the East New Britain Historical and Cultural Centre, Kokopo, East New Britain Province, PNG. Terminology and classification used herein follows that of the *Treatise on Invertebrate Paleontology* and A.M. Clark and Rowe (1971).

SYSTEMATIC DESCRIPTIONS

Class STELLEROIDEA Lamarck 1816
Subclass ASTEROIDEA de Blainville 1830
Order VALVATIDA Perrier 1884
Suborder GRANULOSINA Perrier 1894
Family OPHIDIASTERIDAE Verrill 1867
Genus LINCKIA Nardo 1834

Synonymy

Cribella Agassiz 1835 (*non* Forbes 1841).
Acalia Gray 1840.
Catantes, *Undina* Gistel 1847.

Type species

Linkia typus Nardo 1834 (= *Asterias laevigatus* Linnaeus 1758) by original designation.

***Linckia multifora* (Lamarck 1816)**

Synonymy

Asterias multifora Lamarck 1816, p. 565.
Linckia leachi Gray 1840, p. 285: Mauritius.
Linckia costae Russo 1894, p. 163: Daret Is., Red Sea.

Materials and locality

Two specimens, ANU 60651-2, collected at Ralum, Blanche Bay, East New Britain Province, PNG.

Remarks

Linckia multifora (Lamarck 1816) is widely distributed throughout the Indo-Pacific, from the Red Sea to the Hawaiian Islands (A.M. Clark and Rowe 1971). This record is the first from New Guinea.

Family OREASTERIDAE

Genus PROTOREASTER Döderlein 1916

Type species

Asterias nodosa Linnaeus 1758, p. 420, by subsequent designation.

***Protoreaster nodosus* (Linnaeus 1758)**

Synonymy

Oreaster nodosus, Bell 1884, p. 70; H.L. Clark 1908, p. 280; Fisher 1911, p. 346; H.L. Clark 1921, p. 31.
Pentaceros nodosus, Bell 1899, p. 136.
Protoreaster nodosus, Döderlein 1916, p. 420; H.L. Clark 1946, p. 106; A.M. Clark and Rowe 1971, p. 34, 54; Rowe and Gates 1995, p. 106.

Material and locality

Single beach worn specimen, ANU 60650, collected at Ralum, Blanche Bay, East New Britain Province, PNG.

Remarks

Protoreaster nodosus (Linnaeus 1758) is a common East Indian starfish with a range extending to the West Pacific (Caroline Islands) (H.L. Clark 1946; A.M. Clark and Rowe 1971). Bell (1899) previously described

the species from the collections of Arthur Willey in Blanche Bay. H.L. Clark (1908, p. 280) described variations in specimens from several west New Guinea localities (Humboldt Bay, Sorong, Ansum, Jappen Island). Although the present specimen (R/r = 20/9 mm) has lost most of its granules and abactinal plates, it is identified as a juvenile *P. nodosus* (L.M. Marsh, pers. comm.). It is similar to a specimen of *P. nodosus* in the Western Australian Museum (WAM 599-76: R/r = 27/11 mm) collected by L.M. Marsh from Pulau Langkai, off south Sulawesi, Indonesia. Two juvenile specimens (R = 11-12 mm) from the Andaman Islands, figured and described by Koehler (1910: plate XVI, fig. 1) as *Anthenea* sp., are also very similar to ANU 60650. These specimens may also be *P. nodosus* (L.M. Marsh, pers. comm.).

Class ECHINOIDEA Leske 1778
 Subclass PERISCHOECHINOIDEA M'Coy 1849
 Order CIDAROIDA Claus 1880
 Family CIDARIDAE Gray 1825
 Subfamily STEREOCIDARINAE Lambert 1900
 Genus STEREOCIDARIS Pomel 1883

Synonymy

Typocidaris Pomel 1883
Phalacrocidaris Lambert 1902
Anomocidaris Agassiz and Clark 1907

Type species

Cidaris cretosa Mantell 1835; subsequent designation Lambert and Thiéry 1909 (Feb., p. 31; *non* Mar., where *C. merceyi* was designated, p. 152).

Stereocidaris cf. *squamosa* Mortensen 1928

Figs 2, 3a

Synonymy

Stereocidaris indica Bell 1909, p. 21; H.L. Clark 1925, p. 26.
Stereocidaris squamosa Mortensen 1928b, p. 70; Mortensen 1928a, p. 245.

Material

An incomplete specimen ANU 60638, with an interambulacral plate and portion of ambulacral series.

Locality and horizon

Village of Drankei, west bank of Wari River, central southern Manus Island, Manus Province, PNG. Grid reference 060612 Lorengau 1: 100 000 Sheet 8393 (Edition 1). The collection horizon is an outlier of the (lower) Mundrau Limestone. A sample of limestone from a nearby outlier of the Mundrau Limestone at Metawarei village, 0.5 km northwest of Drankei village, contained a foraminiferal assemblage of mid or upper Tf1 age, and suggests a late Lower

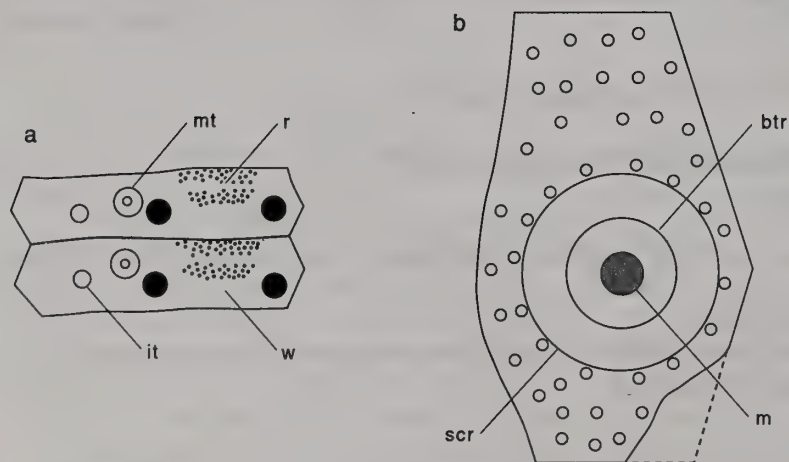


Figure 2. *Stereocidaris* cf. *squamosa* Mortensen 1928. Lower-Middle Miocene, Manus Island, Manus Province. 2a-b, plating diagrams at ambitus for ambulacrum, interambulacrum. Abbreviations: btr basal terrace; it inner tubercle; m mamelon; mt marginal tubercle; r ridge; scr scrobicular ring; w wall.

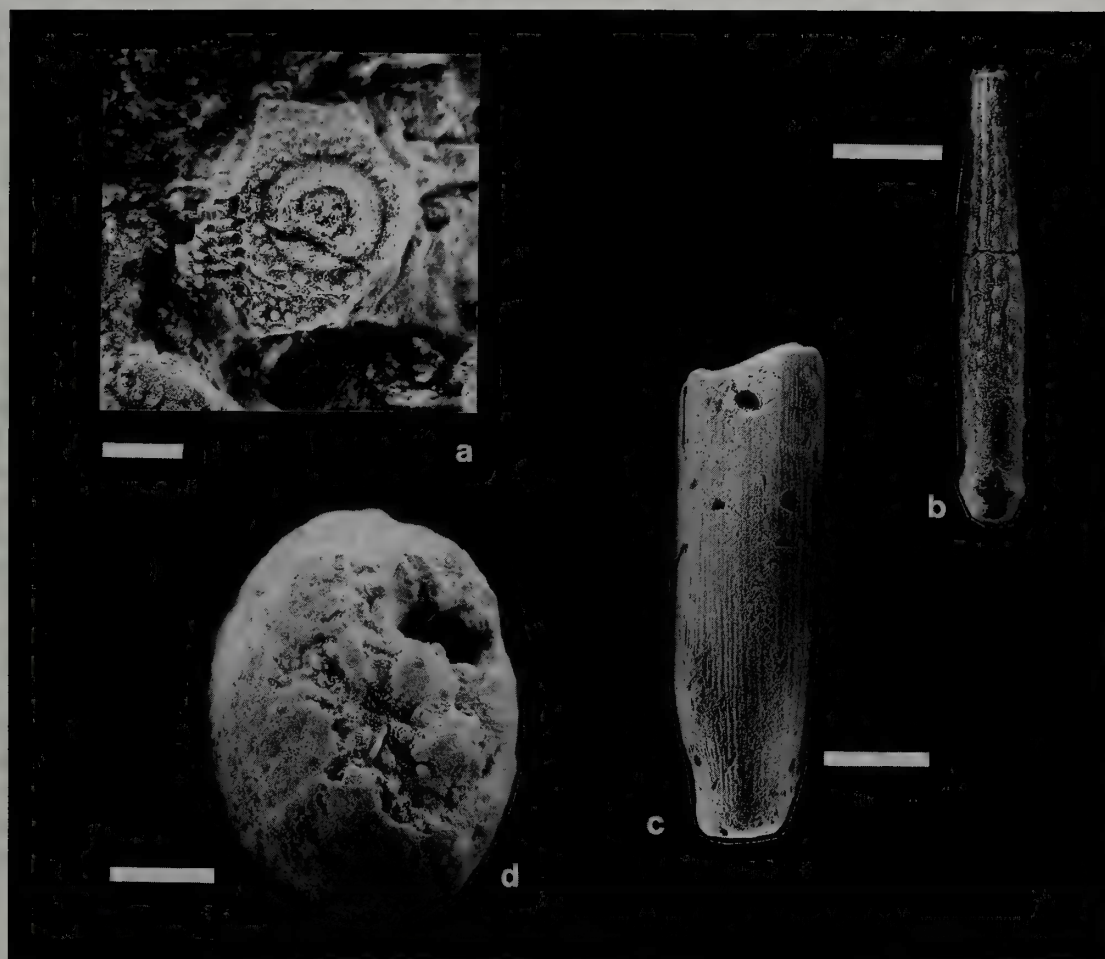


Figure 3. Tertiary echinoids from the Bismarck Archipelago. *Stereocidaris* cf. *squamosa* Mortensen 1928. Lower-Middle Miocene, Manus Island, Manus Province. 3a, ANU 60638, incomplete interambulacral plate with large tubercle and part of adjacent ambulacral plating (refer to Figs 2a, b for plating diagram). Bar scale = 2.5 mm. *Stereocidaris* sp. Pliocene, Sikut River area, East New Britain Province. 3b, ANU 60639, primary spine. Bar scale = 2.5 mm. *Phyllacanthus* sp. Pliocene, Mevelo River area, East New Britain Province. 3c, ANU 60637, proximal portion of primary spine. Bar scale = 5 mm. *Echinoneus* sp. Pleistocene-Holocene, Boang Island, Tanga Group, New Ireland Province. 3d, ANU 60640, aboral view of worn specimen. Bar scale = 5 mm.

Miocene or earliest Middle Miocene age for the unit (Francis 1985).

Description

Test size and shape unknown.

Ambulacra sinuate, rather broad, ca. 39% of width of interambulacra. Interporiferous zone about twice width of a pore-zone. Interporiferous zone with distinctly vertical series of marginal tubercles and inner tubercles; marginal tubercles slightly larger than those of inner series. Pores are rather small, circular, nonconjugate and separated by a broad wall; ridge low and narrow. The arrangement of pores and tubercles in ANU 60638 is strikingly similar to that described for *Stereocidaris squamosa* Mortensen 1928 by Mortensen (1928a: 245 and Plate LXX, fig. 7).

Interambulacral plate higher than broad (height:width = 8.0:5.5) with aureole of moderate size but not very deep, well separated. The very high plate of ANU 60638 exhibits a broad military covered space between

successive aureoles, one unequal to the other, indicating it to be from an upper interambulacral, or aboral, position on test (Fig. 2). Mamelon apparently large, the part of plate is damaged in ANU 60638. Edge of aureole is not raised, and the scrobicular tubercles are not prominent. Outside the scrobicular ring, the interambulacral plate has a sparse to moderate covering of tubercles of similar size to scrobicular tubercles. On the adradial edge of plate there are a few secondary tubercles outside the scrobicular ring.

Apical and periproctal systems unknown.

Details of primary and secondary spines unknown.

Remarks

Stereocidaris Pomel 1883 is a well characterised genus with both fossil and extant species (Mortensen 1928a; Chapman and Cudmore 1934). The genus is distinctive for its usually very high interambulacral plates, ambulacra that are generally conspicuously sinuate and nonconjugate pores (Mortensen 1928a; Fell 1966). The oldest occurrence of the genus is from the Cretaceous of Europe. In the Tertiary it is known from the Eocene of Europe and Australia, Oligocene of New Zealand, Miocene of Australia and Indonesia, and Pliocene of Australia and New Zealand (Mortensen 1928a; Chapman and Cudmore 1934; Fell 1966). Mortensen (1928a) noted the lack of fossil *Stereocidaris* from the Indo-Pacific, with K. Martin's (1918) record of the occurrence of a spine of *Dorocidaris papillata* (= *Stereocidaris*) from the Miocene of Java the only known fossil. This may well represent a collection bias. Extant species of *Stereocidaris*, numbering 15, with nine subspecies, are distributed throughout the Indo-Pacific, including southeast Africa (Mortensen 1928a). Notably the genus has not been recorded from Australasian seas (H.L. Clark 1925; Fell 1966).

The Manus Island specimen, represented by a small fragment of plating from an adapical position, is tentatively assigned to *Stereocidaris squamosa* Mortensen 1928. As already noted, the striking resemblance of the ambulacral and interambulacral plating of this single specimen to that described by Mortensen (1928a) for *S. squamosa* cannot be ignored. *Stereocidaris squamosa* is an extant species recorded from 270 m depth on the Saya de Malha Bank (10° 30'S), about 800 km southeast of the Seychelles in the Indian Ocean (Mortensen 1928a). The species has a small-moderate sized test that ranges in diameter from 30-47 mm, with height from 18.5-29 mm (Mortensen 1928a). Longest spines range in length from ca. 50-59 mm. The late Lower Miocene/earliest Middle Miocene Manus Island occurrence represents the first fossil occurrence of test remains of *Stereocidaris* from the Indo-Pacific.

Stereocidaris sp.

Fig. 3b

Material

An isolated fragmentary spine, ANU 60639.

Locality and horizon

Collected '5 km east of the intake structure of the Warangoi hydro-scheme' (Lindley unpubl. field notes), in the headwaters of Matuli Creek, a tributary of the Warangoi River, Sikut area, northeastern Gazelle Peninsula, East New Britain Province, PNG. Grid reference 081961 Merai 1: 100 000 Sheet 9388 (Edition 1). The collection horizon is from the Sinewit Formation, of Mio-Pliocene age (Lindley 1988). However, fossil evidence and a K-Ar radiometric age from the Sikut and adjacent areas, indicates the formation in this area is restricted to the Pliocene (Read 1965; B. McGowran in Lindley 1988; Lindley 1988; Corbett et al. 1991).

Description

No test fragments which belong to this species have been identified.

Primary spine cylindrical, distinctly fusiform, tapering, point not widened. Spine length 15 mm, with maximum diameter of 2 mm occurring about 1/2 distance from proximal end. The shaft with about 16 series of low rounded warts; only towards the point do they assume the shape of low rounded ridges. The collar is only 0.75-1 mm long, slightly increasing in thickness towards inconspicuous milled ring. Neck is equal in length to collar.

Remarks

The primary spines of cidaroids possess a distinctive structure with a compact outer or cortex layer

covering all except the collar and enveloping a central core consisting of an irregular calcareous meshwork (Mortensen 1928a). The cortex layer is found only in a few other echinoids, mainly the salenids, and spinule and wart ornament along the shaft is formed by this alone (Mortensen 1928a). Mortensen (1928a: 50) considered that primary spine shape and structure is of considerable use in cidaroid classification, both at specific and generic levels.

The primary spine ANU 60639 is identified as that of a cidaroid by its spine shape and its possession of an outer cortex layering. The nature of the inner central core meshwork is clearly visible on the spine collar. The nature of wart development, the number of longitudinal series, and their distal transition to low rounded ridges, bears a strong resemblance to that seen in the primary spines of some extant species of *Stereocidaris*, including *Stereocidaris grandis* (Döderlein) and *Stereocidaris hawaiiensis* Mortensen 1928b, found only in Japanese seas and Hawaiian seas, respectively (cf. Mortensen 1928a: Plate XIX, fig. 5 and XXI, fig. 5, respectively).

Subfamily RHABDOCIDARINAE Lambert 1900, emended Fell 1966

Genus PHYLLACANTHUS Brandt 1835

Synonymy

Leiocidaris Desor 1885, p. 48.

Type species

Cidarites (Phyllacanthus) dubia Brandt 1835, p. 67, by original designation.

Phyllacanthus sp.

Fig. 3c

Material

One isolated fragmentary spine, ANU 60637.

Locality and horizon

Collected in stream float from an unnamed large western tributary of Mevelo River, Lakit Range, southwestern Gazelle Peninsula, East New Britain Province, PNG. Grid reference 660623 Pondo 1:100 000 Sheet 9288 (Edition 1). Lakit Limestone, Pliocene (Lindley 1988).

Description

No test fragments which belong to this species have been identified.

Proximal portion of primary spine moderately thick, cylindrical, fusiform, with a maximum diameter of 8.0 mm. Details of distal shaft unknown. Details of spine base, milled ring and collar unknown. Spine swells rapidly above the collar. Surface of shaft is finely and uniformly granulated (not visible to the naked eye), the granules forming numerous (> 50) longitudinal series along length of spine.

Remarks

Lindley (2003b) described the spines of *Phyllacanthus imperialis* var. *javana* K. Martin 1885 and *Phyllacanthus* sp. from the Lower Pliocene Kairuku Formation, Yule Island. Unfortunately, the characters diagnostic of these species, including spine collar length and the number of ridges on the distal part of the spine, are not visible on ANU 60637.

Subclass EUECHINOIDEA Bronn 1860

Superorder ECHINACEA Claus 1876

Order TEMNOPLEUROIDA Mortensen 1942

Family TOXOPNEUSTIDAE Troschel 1872

Genus TOXOPNEUSTES A. Agassiz 1841

Synonymy

Boletia Desor 1846, p. 362.

Type species

Echinus pileolus Lamarck 1816, p. 45, by original designation.

Toxopneustes pileolus (Lamarck 1816)

Synonymy

Echinus pileolus Lamarck 1816, p. 45.

Toxopneustes pileolus, A. Agassiz 1841, p. 7; H.L. Clark 1925, p. 123; Mortensen 1943a, p. 472;
A.M. Clark and Rowe 1971, p. 156; Rowe and Gates 1995, p. 258.

Mortensen (1943a: 472) lists additional synonymies.

Material and locality

Single naked test, B20022, from the vicinity of Cape Gazelle, New Britain, East New Britain Province, PNG.

Remarks

Toxopneustes pileolus (Lamarck 1816) is widely distributed throughout the Indo-West Pacific (Mortensen 1943a; A.M. Clark and Rowe 1971; Miskelly 2002).

Genus TRIPNEUSTES L. Agassiz 1841

Type species

Echinus granularis Lamarck 1816, p. 44, by original designation.

Tripneustes gratilla (Linnaeus 1758)

Synonymy

Echinus gratilla Linnaeus 1758, p. 664.

Tripneustes gratilla, H.L. Clark 1925, p. 124; Mortensen 1943a, p. 500; A.M. Clark and Rowe 1971,
p. 156; Rowe and Gates 1995, p. 259.

Mortensen (1943a: 500) lists additional synonymies.

Material and locality

Single naked test, B20023, from the vicinity of Cape Gazelle, New Britain, East New Britain Province, PNG.

Remarks

Tripneustes gratilla (Linnaeus 1758) is widely distributed throughout the Indo-West Pacific (Mortensen 1943a; A.M. Clark and Rowe 1971). Previous records from the Pacific include the Marshall Islands, Norfolk Island, Hawaiian Islands, Kermadec Islands, Solomon Islands, Fiji and Hood Lagoon, south coast of Papua (H.L. Clark 1925; Mortensen 1943a; A.M. Clark and Rowe 1971; Miskelly 2002).

Order ECHINOIDA Claus 1876

Family ECHINOMETRIDAE Gray 1825

Genus ECHINOMETRA Gray 1825

Synonymy

Ellipsechinus Lütken 1864, p. 165.

Plagiechinus Pomel 1883, p. 78.

Mortensenia Döderlein 1906, p. 233.

Type species

Echinus lucunter Linnaeus 1758, p. 665, by original designation.

Echinometra mathaei (de Blainville 1825)

Synonymy

Echinus lucunter Lamarck 1816, p. 50 (*non E. lucunter* Linnaeus).

Echinometra mathaei, H.L. Clark 1925, p. 143; H.L. Clark 1932, p. 216; Mortensen 1943b, p. 381;

H.L. Clark 1946, p. 332; A.M. Clark and Rowe 1971, p. 157; Rowe and Gates 1995, p. 211.

Mortensen (1943b: 381) lists additional synonymies.

Material and localities

Fourteen naked tests from Gargaris village, northern coast of Malendok Island, Tanga Group, New Ireland Province, PNG; one partly naked test from beach at Ralum, Blanche Bay, East New Britain Province, PNG; one naked test from Penlolo village, south coast of New Britain, West New Britain Province, PNG; one naked test, B 20016, from Cape Gazelle, New Britain, East New Britain Province, PNG.

Remarks

Echinometra mathaei (de Blainville 1825) is a long ranging species, recorded from late Lower Miocene-early Middle Miocene rocks in the western and eastern Mediterranean Sea (Negretti et al. 1990). Extant *E. mathaei* is one of the most widely distributed echinoids, occurring throughout tropical-subtropical waters of the Indo-West Pacific (Mortensen 1943b; A.M. Clark and Rowe 1971). H.L. Clark (1908) recorded the species from Sorong, west New Guinea and Miskelly (2002) recorded it from the Solomon Islands. This record indicates a wide distribution throughout the Bismarck Archipelago (Tanga Group, New Ireland; Blanche Bay, New Britain; and south coast New Britain).

Genus HETEROCENTROTUS Brandt 1835

Synonymy

Acroladia L. Agassiz and Desor 1846, p. 373.

Type species

Echinus mamillatus Linnaeus 1758, p. 664, by subsequent designation of Pomel 1883, p. 77.

Heterocentrotus mammillatus (Linnaeus 1758)

Synonymy

Echinus mamillatus Linnaeus 1758, p. 664.

Heterocentrotus mammillatus, H.L. Clark 1925, p. 147; Mortensen 1943b, p. 409; H.L. Clark 1946, p. 333; A.M. Clark and Rowe 1971, p. 158; Rowe and Gates 1995, p. 213.

Mortensen (1943b: 409) lists additional synonymies.

Material and locality

A single naked test, B 20017, and unlabelled isolated spines (housed in the East New Britain Historical and Cultural Centre, Kokopo) from Cape Gazelle, New Britain, East New Britain Province, PNG; an isolated primary spine, ANU 60648, from Nosnos village, Boang Island, Tanga Group, New Ireland Province, PNG.

Remarks

Heterocentrotus mammillatus (Linnaeus 1758) is widely distributed throughout the Indo-Pacific, from the Gulf of Suez and Madagascar to the Hawaiian Islands and Fiji (Mortensen 1943b). It is recorded from the Solomon Islands by Miskelly (2002). The largest test of *H. mammillatus* noted by Mortensen (1943b) has a long diameter of 82 mm, with most individuals having diameters of 72 mm or less. The long diameter of the Cape Gazelle test is 72 mm. The Tanga spine has a length of 74 mm and, given that the primary spines of *H. mammillatus* usually do not exceed the long diameter of the test (Mortensen 1943b), appears to have come from a relatively large individual.

Genus HELIOCIDARIS L. Agassiz and Desor 1846.

Synonymy

Toxicidaris A. Agassiz 1863, p. 22.

Type species

Echinus tuberculatus Lamarck 1816, p. 50, by original designation.

Diagnosis

Low hemispherical echinoids, widest at circular ambitus. Ambulacral plates with 7 or more pore-pairs to each plate; arcs may be irregularly double; expanded poriferous tracts of the flattened adoral surface are petaloid. Oculars I and IV usually insert. Gill-slits are shallow (Philip 1965; Fell and Pawson 1966).

Remarks

Heliocidaris L. Agassiz and Desor 1846 is distributed along the southern coasts of Australia, northern New Zealand, Kermadec Islands and Lord Howe Island (Mortensen 1943a). Two species are included in the genus by Mortensen (1943a), viz: *Heliocidaris tuberculata* (Lamarck 1816) and *Heliocidaris erythrogramma* (Valenciennes 1846) and, given their similar morphologies, he has questioned whether they are really conspecific. *Anthocidaris* Lütken 1864 is a closely allied genus (only known species *Anthocidaris crassispina* [A. Agassiz 1863]) from the coasts of southern Japan and China, distinguished from *Heliocidaris* by the spicules of the tube feet (Mortensen 1943a). On the status of *Anthocidaris*, Mortensen (1943a: 328) questioned whether the genus should be merged into *Heliocidaris*. Philip (1965) described the only known fossil representative of the genus, *Heliocidaris ludbrookae* Philip 1965 from the Lower-early Middle Miocene (Longfordian-Batesfordian) of southeastern Australia.

Heliocidaris robertsi sp. nov.

Figs 4, 5a-e

Diagnosis

Test low hemispherical, somewhat inflated above. Ambulacral plates with 12 pore-pairs per plate; ambital and aboral pore-arcs doubled. Ambulacral and interambulacral plates relatively large; each bearing a primary tubercle and numerous secondary tubercles; aureoles of primaries not in contact. Primary tubercles of ambital and aboral ambulacral plates with an aborally positioned secondary tubercle.

Etymology

Named for Mr Michael Roberts, amateur conchologist of Kokopo, East New Britain Province, PNG.

Material and locality

Single naked test, ANU 60654, from the vicinity of Cape Gazelle, New Britain, East New Britain Province, PNG.

Description

Test low hemispherical, somewhat inflated above, widest at circular ambitus. The oral side is flattened, scarcely sunken towards the peristome. Only specimen of 38 mm diameter.

The pore zones are conspicuously petaloid on the

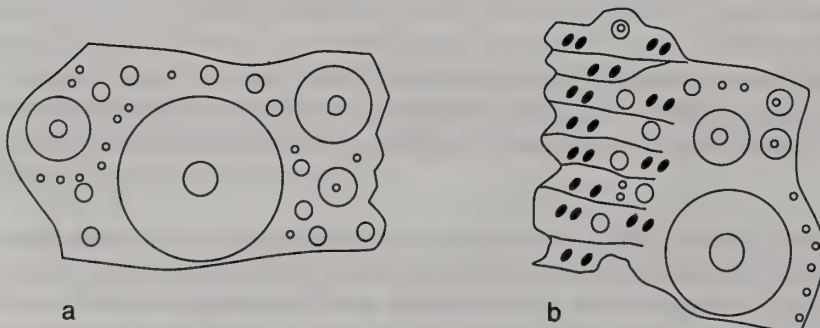


Figure 4. *Heliocidaris robertsi* sp. nov. Cape Gazelle area, East New Britain Province. 4a-b, plating diagrams at ambitus for interambulacrum, ambulacrum.

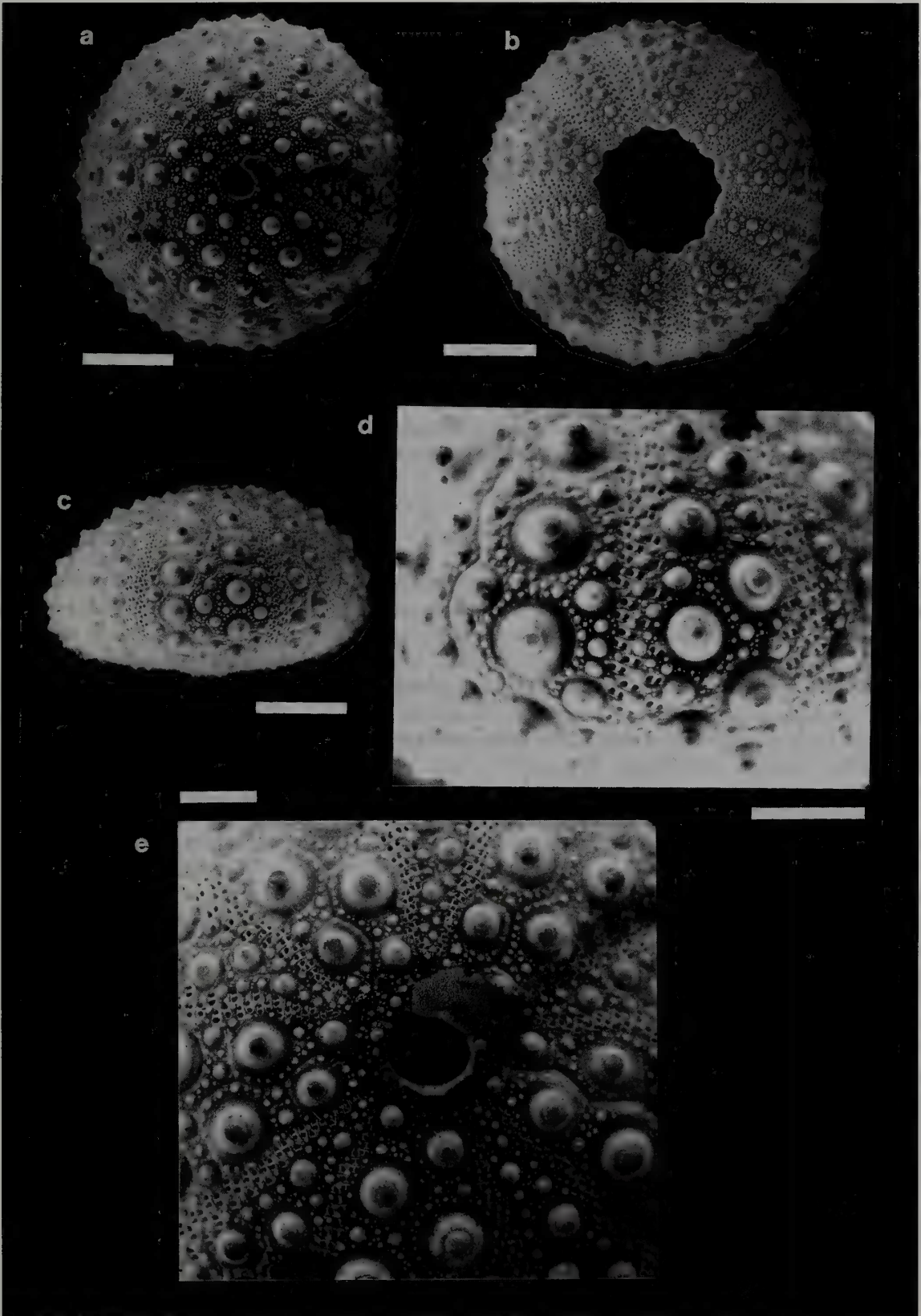


Figure 5. *Heliocidaris robertsi* sp. nov. Cape Gazelle area, East New Britain Province. 5a-e, ANU 60654, aboral, oral, lateral views. Bar scale = 10 mm; ambulacral plating at ambitus (refer to Fig. 4b for plating diagram). Bar scale = 5 mm; apical disc. Bar scale = 2.5 mm.

oral surface, about 1.5-2 times the width of interporiferous zone. The pore-series in this area are almost horizontal and are separated by secondary tubercles forming a single prominent vertical series; scattered miliary tubercles are also present. In the ambital region there are 12 pore-pairs arranged in double arcs (Fig. 4). Above the ambitus the pore-zones become much narrower. Primary tubercles in the ambital zone are large, almost as large as the interambulacral primaries; aureoles of adjacent primaries in each vertical series widely separated. Sutures between adjacent plates are seen very distinctly on the outer adoral side of the boss. Each ambulacral plate at and above the ambitus has a prominent secondary tubercle positioned aborally to the primary tubercle; 4-5 other secondary tubercles are also present. Miliaries tend to be arranged along the perradial sutures of ambital and superoambital ambulacrals; elsewhere on each plate only a sparse covering of miliaries is present.

The interambulacral primaries are large, forming prominent series aborally; their aureoles are distinctly separated, leaving a broad space at the upper edge of each plate, occupied by several small tubercles and miliaries. Usually sutures between adjacent plates are close to, but do not cross, aureole of successive tubercle. In the median space there is on the oral surface and in the ambital region a conspicuous double series of secondary tubercles about half the size of the ambulacral primaries. Below the ambitus all the tubercles decrease rapidly in size, with the secondaries disappearing, and only the primaries continuing to the peristome.

The apical system is small, only about 18 percent of the test diameter. There is typically one large tubercle on each genital plate, except the very large madreporite, and a scattering of small tubercles over the remainder (Fig. 5e). Ocular I and IV are broadly insert. The peristome is very small, about 29 percent of test diameter. Gill-slits shallow.

Details of spines and pedicellariae unknown.

Remarks

Heliocidaris robertsi sp. nov. is readily distinguished from *H. tuberculata* and *H. erythrogramma* and the closely allied *A. crassispira* by its possession of double pore-arcs on the adoral surface. The double pore-arcs of *H. robertsi* are very similar to those of *Heterocentrotus trigonarius* (Lamarck 1816), figured by Mortensen (1943a: fig. 132c) and Fell and Pawson (1966: fig. 324, 7c). However, any resemblance between the new species and *H. trigonarius* is easily discounted because of the latter's possession of a distinctly elongated test and a significantly larger peristome (51 percent of test diameter).

The biogeographical position of *H. robertsi* is noteworthy in that it is the tropical representative of two closely allied temperate water genera, *Heliocidaris*, a very common form restricted to southern Australia and New Zealand, and *Anthocidaris*, an equally common form restricted to Japan and China.

Pore-arc doubling is almost as strongly developed in other echinometrids including *Colobocentrotus* Brandt 1835 and *Zenocentrotus* A.H. Clark 1931, and incipient development may also be seen in *Echinometra* Gray 1825 (Mortensen 1943a: 281). All three genera possess an elliptical or oblong ambitus. The functional significance of doubling of pore-arcs in compound plates relates to (a) increasing the area over which tube-feet are spread, and thereby increasing respiratory and feeding efficiency (Mortensen 1943a; Woods 1958; Durham 1966; A.M. Clark 1968) and (b) strengthening of the test (Durham 1966). The doubling of pore-arcs on the aboral surface of *H. robertsi* greatly increases the number of tube-feet in this area, not only aiding in improved respiration, but allowing it to catch food particles falling onto its upper surface. With such adaptations to its upper surface, the echinoid may have been a reef rock borer, inhabiting a hole perhaps several centimetres deep.

Superorder GNATHOSTOMATA Zittel 1879

Order HOLECTYPOIDA Duncan 1889

Suborder ECHINONEINA H.L. Clark 1925

Family ECHINONEIDAE Agassiz and Desor 1847

Genus ECHINONEUS Leske 1778

Synonymy

Echinanaus Gray 1825, p. 7 (*nom. van.*).

Pseudohaimea Pomel 1885, p. 118.

Koehleraster Lambert and Thiéry 1921, p. 331.

Type species

Echinoneus cyclostomus Leske 1778, by subsequent designation of H.L. Clark 1917, p. 101.

Remarks

Echinoneus Leske 1778 is an Oligocene-Recent form, with some ten fossil species described from the Oligocene and Miocene of Europe (Mortensen 1948a; Wagner and Durham 1966). Two Recent species are known, viz. *Echinoneus cyclostomus* Leske 1778 and *Echinoneus abnormalis* de Loriol 1883, distinguished by the presence or absence of imperforate primary tubercles and well developed glassy tubercles. Recent forms are distributed throughout the West Indies, Indo-Pacific and Australia. Mortensen (1948a) considered that many of the fossil species are very difficult to distinguish and may in fact be Recent *E. cyclostomus*.

Echinoneus sp.

Fig. 3d

Material

One poorly preserved test, ANU 60640.

Locality and horizon

Nosnos village, Boang Island, Tanga Group, New Ireland Province, PNG. Grid reference 296246 Tanga 1:100 000 Sheet 9591 (Edition 1). Unnamed poorly compacted bioclastic limestone, Pleistocene-Holocene (Wallace et al. 1983).

Description

Test ovoid, moderate size, measuring 23 x 17 x 11.5 mm; oral surface weakly concave. Ambulacra narrow, not petaloid. Other details of ambulacra unknown. Details of interambulacra unknown. Details of tubercles unknown. Apical and periproctal systems unknown.

Remarks

The lack of well preserved tubercles on this specimen makes it difficult to assign a species.

Echinoneus cyclostomus Leske 1778

Synonymy

Echinoneus cyclostomus Leske 1778, p. 173; H.L. Clark 1925, p. 177; H.L. Clark 1946, p. 353; Mortensen 1948a, p. 75; A.M. Clark and Rowe 1971, p. 158; Rowe and Gates 1995, p. 215. Mortensen (1948a: 75) lists additional synonymies.

Material and locality

Twelve naked tests, including ANU 60641, from Gargaris village, northern coast of Malendok Island, Tanga Group, New Ireland Province, PNG; one naked test, B 20021, from Cape Gazelle, New Britain, East New Britain Province, PNG.

Remarks

Echinoneus cyclostomus Leske 1778 is the only known case of a (tropical) cosmopolitan echinoid, having been recorded from the West Indies, Ascension (but not the African west coast) and the Indo-Pacific-East Africa (Zanzibar, Natal), Madagascar to the Pacific islands (Funafuti, Palmyra, Hawaiian Islands), and from Japan to Queensland (Great Barrier Reef) and Lord Howe Island (Mortensen 1948a). Miskelly's (2002) record of *E. cyclostomus* from the Solomon Islands represents the nearest previous record to that from the Tanga Group and Cape Gazelle.

Echinoneus abnormalis de Loriol 1883

Synonymy

Echinoneus abnormalis de Loriol 1883, p. 41; H.L. Clark 1917, p. 102; H.L. Clark 1925, p. 176; Mortensen 1948a, p. 80; A.M. Clark and Rowe 1971, p. 158. *Koehleraster abnormalis* Lambert and Thiéry 1921, p. 331.

Material and locality

One naked test, ANU 60641, from Gargaris village, northern coast of Malendok Island, Tanga Group, New Ireland Province, PNG.

Remarks

This species is represented by a single naked test measuring 30 x 22.5 x 15 mm. *Echinoneus abnormalis* de Loriol 1883 is distinguished from *E. cyclostomus* by possessing perforated, non-glassy spine tubercles. The apical system of the Tanga specimen is distinctly anterior to that of co-occurring specimens of the much more common *E. cyclostomus*. *Echinoneus abnormalis* has a restricted distribution, known from Mauritius (type locality), Kei Islands, Palmyra Island, Banda, Ellice Islands and the Hawaiian Islands (Mortensen 1948a; A.M. Clark and Rowe 1971). The recent record of *E. abnormalis* from the vicinity of Raine Island on the northern Great Barrier Reef (Gibbs et al. 1976) represents the first from Australasian waters. The record from the Tanga Group is the second from the East Indies. The species is observed to be sympatric with the much more common *E. cyclostomus* in many localities, a fact Gibbs et al. (1976) suggested may have resulted in it having gone unrecognised in samples. Mortensen (1948a: 81) considered that the two species probably didn't live together at the same localities. Of the 15 specimens of *Echinoneus* collected from the Malendok Island locality, only one was an *E. abnormalis*, suggesting that in this case, the species' apparent rarity may be related to different niches within the same locality.

Order CLYPEASTEROIDA A. Agassiz 1872

Suborder CLYPEASTERINA A. Agassiz 1872

Family CLYPEASTERIDAE L. Agassiz 1835

Genus CLYPEASTER Lamarck 1801

Type species

Clypeaster rosaceus (Linnaeus 1758), by subsequent designation of Desmoulins 1835.

Clypeaster reticulatus* (Linnaeus 1758)*Synonymy**

Lindley (2003a) lists previous synonymies.

Material

Single naked test, B20020, from the vicinity of Cape Gazelle, New Britain, East New Britain Province, PNG.

Remarks

Clarification of Lindley's (2003a) statement on the distribution of *Clypeaster reticulatus* (Linnaeus 1758) is needed. The species is a very common Indo-West Pacific echinoid, distributed in the western Indian Ocean and the Red Sea, throughout the East Indies and east into the Pacific Ocean to the Hawaiian Islands (A.M. Clark and Rowe 1971). Previous south Pacific records of the species have been made by A. Agassiz (1863), Mortensen (1948b) and A.H. Clark (1954) from the Gilbert Islands, New Caledonia and Marshall Islands, respectively. Mortensen's (1948b) New Caledonian record has not been confirmed by De Ridder (1986: 29). McNamara and Kendrick (1994) have also recorded the species from Barrow Island, northwestern Australia. The species is known from fossil in Java (Lower Miocene), Yule Island, PNG (Lower Pliocene), East Africa (Pliocene-Pleistocene) and the New Hebrides (Pleistocene) (Mortensen 1948b; Lindley 2003a).

Family ARACHNOIDAE Duncan 1889

Subfamily ARACHNOIDINAE Duncan 1889

Genus ARACHNOIDES Leske 1778

Synonymy

Echinarchinus Leske 1778, p. 217.

Type species

Echinus placenta Linnaeus 1758, p. 666, ICZN 1954.

Arachnoides placenta (Linnaeus 1758)

Synonymy

Echinus placenta Linnaeus 1758, p. 666.

Arachnoides placenta (Linnaeus 1758): L. Agassiz 1841, p. 94; Bell 1899, p. 136; H.L. Clark 1925, p. 154; H.L. Clark 1946, p. 340; A.M. Clark and Rowe 1971, p. 161; Rowe and Gates 1995, p. 176.

Mortensen (1948b) lists additional synonymies.

Material and locality

Single naked test, B20018, from the vicinity of Cape Gazelle, New Britain, East New Britain Province, PNG.

Remarks

Arachnoides placenta (Linnaeus 1758) is a common littoral species throughout the East Indies and the south Pacific (Mortensen 1948b; A.M. Clark and Rowe 1971). The first record of the species from the Bismarck Archipelago is that of Bell (1899) from an unspecified locality in New Britain.

Suborder LAGANINA Mortensen 1948

Family LAGANIDAE A. Agassiz 1873

Genus LAGANUM Link 1807

Synonymy

Lagana Gray 1825, p. 427.

Type species

Laganum petalodes (= *Echinodiscus laganum* Leske 1778, p. 204), by original designation.

Laganum laganum (Leske 1778)

Synonymy

Laganum Bonani Klein 1734, p. 25.

Echinodiscus laganum Leske 1778, p. 204.

Laganum laganum, Mortensen 1948b, p. 312.

Laganum depressum, Lindley 2001, p. 130.

Mortensen (1948b: 312) list previous synonymies.

Material and locality

Single test, ANU 60649, from Penlolo village, south coast of New Britain, West New Britain Province, PNG.

Remarks

Laganum laganum (Leske 1778) is distinct with its pentagonal test with thick, swollen edges, and an oblong-elongate periproct situated midway between the mouth and test edge. The species is common in the East Indies, and is also recorded from Port Jackson and Tasmania (Mortensen 1948b). Mortensen (1948b) also recorded it from the Bismarck Archipelago (Table 2). H.L. Clark (1908) recorded the species from Saonek, Waigiou Island, in west New Guinea (Fig. 1)

Suborder SCUTELLINA Haeckel 1896

Family ASTRICLYPEIDAE Stefanini 1911

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Genus ECHINODISCUS Leske 1778

Type species

Echinodiscus bisperforatus Leske 1778, p. 196.

Echinodiscus tenuissimus (L. Agassiz in Agassiz and Desor 1847)

Synonymy

Lobophora tenuissima L. Agassiz and Desor 1847, p. 136.

Echinodiscus tenuissimus, Gray 1855, p. 20; H.L. Clark 1914, p. 71; H.L. Clark 1925, p. 171;

Mortensen 1948b, p. 411; A.M. Clark and Rowe 1971, p. 144 162; Rowe and Gates 1995, p. 185.

Mortensen (1948b: 411) lists additional synonymies.

Material and locality

Two tests, B 20024 (naked) and B 20025 (with spines), from the vicinity of Cape Gazelle, New Britain, East New Britain Province, PNG.

Remarks

Echinodiscus tenuissimus (L. Agassiz in Agassiz and Desor 1847) is a widely distributed Indo-West Pacific form, occurring throughout the East Indies, northern Australia, southern Japan and the south Pacific (Mortensen 1948b; A.M. Clark and Rowe 1971). In the south Pacific, the species is recorded from Tanna, Vanuatu, (H.L. Clark 1925) and from New Caledonia (A.M. Clark and Rowe 1971). However, De Ridder (1986) only noted the occurrence of *Echinodiscus bisperforatus* Leske 1778 from New Caledonia. H.L. Clark (1925) observed that New Caledonian specimens of *E. tenuissimus* in the British Museum (Natural History) have a form more like *E. bisperforatus*. The Cape Gazelle specimens have very short lunules, about one quarter the length of the radius taken through them, and there is no difference in the tuberculation and spines of the ambulacral and interambulacral areas of the oral surface, both diagnostic characters of *E. tenuissimus* (Mortensen 1948b; A.M. Clark and Rowe 1971).

Superorder ATELOSTOMATA Zittel 1879

Order SPATANGOIDA Claus 1876

Suborder HEMIASTERINA Fischer 1966

Family SCHIZASTERIDAE Lambert 1906

Genus SCHIZASTER L. Agassiz 1836

Type species

Schizaster studeri L. Agassiz 1836, p. 185, by subsequent designation ICZN 1948.

Remarks

McNamara and Philip (1980a, b) questioned the familial classification of the spatangoids used by Mortensen (1951) and Fischer (1966) and, in particular, the Family Schizasteridae. Within the Schizasteridae McNamara and Philip recognized genera sharing the gross morphological test features of *Schizaster*, viz. a posteriorly located apical system, with the apex of the test posterior to this; a long, typically sunken, poriferous frontal ambulacrum; and sunken petals, of which the posterior pair are markedly shorter than the anterior ones. Within this group, McNamara and Philip (1980a, b) included the genus *Schizaster* L. Agassiz 1836 (with its subgenera *Dipneutes* Arnaud 1891; *Paraster* Pomel 1869 and *Ova* Gray 1825 [= *Diploraster* Mortensen 1951]); *Brisaster* Gray 1855; *Kina* Henderson 1975; *Moir* L. Agassiz 1872 (= *Moiropsis* L. Agassiz 1881); and *Proraster* Lambert 1895 (= *Hypselaster* Clark 1917). The author accepts their emended diagnosis for *Schizaster*.

Subgenus PARASTER Pomel 1869

Type species

Schizaster gibberulus L. Agassiz 1847, by original designation of Pomel 1869, p. 14.

Diagnosis

Species of *Schizaster* with a small to moderate sized test, with a shallow frontal sinus. Apical system slightly posterior of centre. Frontal ambulacrum shallow with pore pairs inclined at about 45° and arranged in single rows. Anterior petals almost straight, diverging at an angle up to 110° (McNamara and Philip 1980a).

Remarks

There is difficulty in placing the Cape Gazelle species firmly within McNamara and Philip's (1980a) subgenus *Paraster* Pomel 1869. This is particularly in relation to details of the anterior petals, their flexed nature and 80° angle of divergence, both characters diagnostic of subgenus *Schizaster* L. Agassiz 1836. The frontal ambulacrum does not possess the steeper sided walls typical of species referred to *Schizaster* (*Schizaster*) (McNamara and Philip 1980a). Furthermore, McNamara and Philip (1980a) noted that species referred to *Schizaster* (*Schizaster*) possess a more elongate, narrower test than those assigned to *Paraster*. The Cape Gazelle species is assigned to *Schizaster* (*Paraster*) by its possession of a small test, shallow frontal sinus, apical system slightly posterior of centre and shallow frontal ambulacrum with pore pairs inclined at about 45°. The species is probably morphologically transitional between the *Paraster* and *Schizaster* morphotypes.

***Schizaster* (*Paraster*) *ovatus* sp. nov.**

Figs 6a-d

Diagnosis

A small species of *Schizaster* (*Paraster*) with a moderately depressed, ovoid test; apical system is 55 percent of test length from anterior, with four genital pores. Anterior ambulacrum relatively narrow and shallow; pore pairs inclined at about 45° and arranged in single rows; outer pores elongate, with similarly sized inner pores comma-shaped. Frontal sinus shallow.

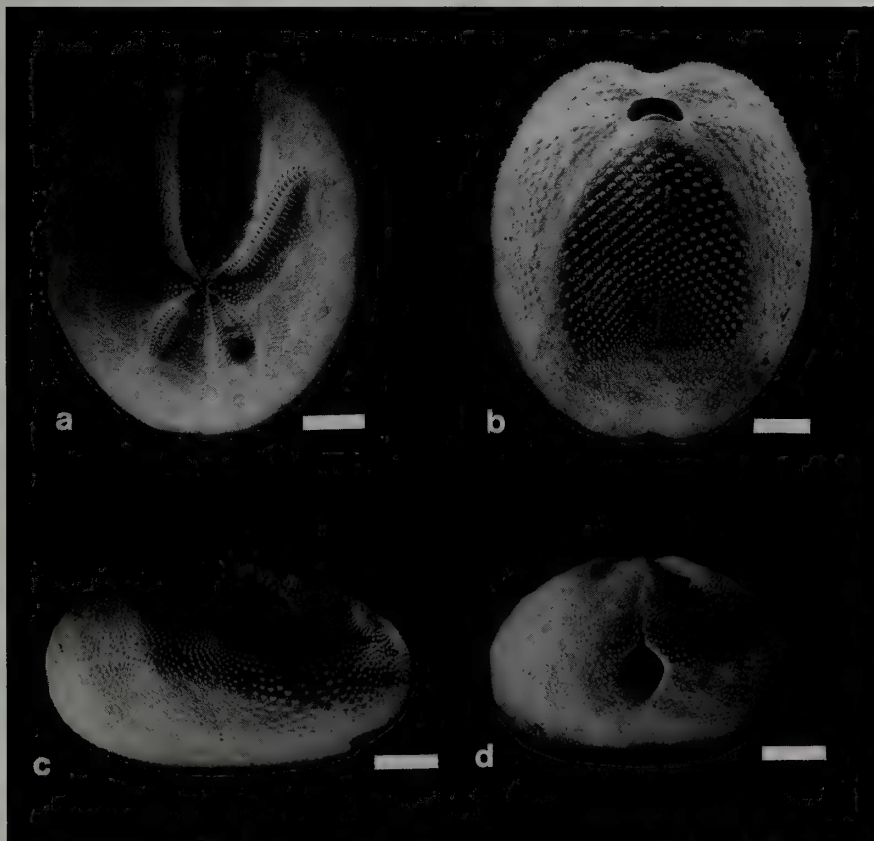


Figure 6. *Schizaster* (*Paraster*) *ovatus* sp. nov. Cape Gazelle, East New Britain. 6a-d, ANU 60653, aboral, oral, lateral, posterior views. Bar scale = 2.5 mm.

Etymology

Ovatus L. egg-shaped, in reference to the form of the test, distinctive amongst the Schizasteridae.

Material and locality

Holotype ANU 60653, a complete naked test from the vicinity of Cape Gazelle, New Britain, East New Britain Province, PNG.

Description

Test of small size, elongate ovoid, with length x width x height measuring 34 x 28 x 18 mm; test length:width = 1.21, width:height = 1.55. Test moderately depressed, with apical system located 55 percent of test length from anterior; test highest posterior to apical system, along keel of ambulacrum V. Oral surface is gently

convex. Apical system ethmolytic, depressed, with four genital pores, posterior pair being larger than anterior pair. Frontal ambulacrum long, shallow and narrow (12 percent of test length); pore pairs inclined at about 45° and arranged in a single row. Outer pores elongate, with similarly sized inner pores comma-shaped. Frontal sinus broad and shallow. Interambulacra II and III form sharp, high keels. Anterior petals diverging at angle of 80°; flexed distally and shallow, bearing pore pairs which are elliptical, widely spaced and conjugate; 26 pairs are present. Posterior petals are moderately long (occupying 21 percent of test length), bearing 18 pore pairs.

Peripetalous fasciole is distinct, passing transversely between posterior petals and thickening at petal ends; the fasciole describes a concave arc between the extremities of the posterior and anterior petals, with an outwards flexure, corresponding with a constriction, forward of the apical system. Fasciole reaches maximum thickness at the extremities of the anterior petals. Peripetalous fasciole passes forward from anterior petals at about 60° before curving strongly to close with frontal ambulacrum; constrictions occur on interambulacral keel and adjacent to the abrupt curvature. Lateroanal fasciole is narrower than peripetalous fasciole and of more constant width. Lateroanal fasciole extends abaxially posteriorly from peripetalous fasciole at constriction between posterior and anterior petals; at ambitus it runs far below periproct, close to adoral surface.

Peristome oval and slightly sunken; situated anteriorly, anterior tip of labrum 15 percent of test length from anterior. Anteriorly labrum is strongly curved; bounded by thick rim that degenerates laterally. Labrum as long as broad; posterior extension triangular, about as long as broad. Labrum carries several small tubercles anteriorly. Plastron is pear-shaped and broad, maximum width being 3/4 length. Plastron tubercles are arranged in curving rows.

Periproct at mid-level on sub-truncate end of test. Periproct longitudinally elliptical, with a prominent narrow slit extending a short distance axially and aborally towards interambulacrum V, nearly reaching apical surface (Fig. 6d).

Remarks

Schizaster (Paraster) ovatus sp. nov. can be distinguished from other *Schizaster*-like heart urchins by its small, distinctively narrower and less inflated test, and long, shallow and narrow frontal ambulacrum. The test L:W and L:H ratios of 1.21 and 1.88 are larger than for most other echinoids of this group. The presence of four genital pores would suggest that the holotype is a mature specimen. McNamara and Philip (1980b) noted that in *Schizaster (Ova) myorensis* McNamara and Philip (1980b) the onset of maturity, occurring at a test length of about 25 mm, followed the sequential opening of the first, second, third and fourth genital pores.

Morphological adaptations in *Schizaster*-like heart urchins are related to a need to produce a more efficient current flow over the aboral surface in sediment of low permeability (McNamara and Philip 1980a). The posterior migration of the apex meant more water would flow over the frontal sinus to the peristome; the deepening of the frontal ambulacrum and the frontal sinus assisted in channelling water to the peristome; and the deep and long frontal ambulacrum further enabled more-funnel-building tube feet to be accommodated, presumably in response to finer-grained sediment (McNamara and Philip 1980a). The weakly vaulted test of *S.(P.) ovatus* with its shallow, open frontal ambulacrum and shallow frontal sinus suggests the species was a shallow-burrower in coarse (permeable) shell gravel.

Suborder MICRASTERINA Fischer 1966

Family BRISSIDAE Gray 1855

Genus BRISSUS Gray 1825

Synonymy

Bryssus Martens 1869, p. 128 (*nom. van.*).

Brissus (Allobrissus) Mortensen 1950, p. 162.

Type species

Spatangus brissus unicolour Leske 1778, p. 248 by subsequent designation of ICZN, Op. 290 1948.

Brissus (Brissus) latecarinatus (Leske 1778)

Synonymy

Brissus carinatus Gray 1825, p. 431; A. Agassiz 1872-74, p. 96, 596.

Brissus latecarinatus (Leske 1778): H.L. Clark 1921, p. 153; H.L. Clark 1925, p. 219; H.L. Clark

1946, p. 375; Mortensen 1951, p. 514; A.M. Clark and Rowe 1971, p. 165; Gibbs et al. 1976, p. 135.

Brissus (Brissus) latecarinatus: Rowe and Gates 1995, p. 187.

Spatangus Brissus latecarinatus Leske 1778, p. 249.

Mortensen (1951: 514) lists additional synonymies.

Material and locality

Three naked tests, ANU 60643-5, from Nosnos village, Boang Island, Tanga Group, New Ireland Province, PNG; one naked test, B 20014, from Cape Gazelle, New Britain, East New Britain Province, PNG.

Remarks

Brissus (Brissus) latecarinatus (Leske 1778) is a widely distributed species throughout the Indo-Pacific (Mortensen 1951; A.M. Clark and Rowe 1971). It is present on Australian coasts, from Queensland to Port Jackson, and is also known from Lord Howe Island (H.L. Clark 1946). Miskelly's (2002) record of the species from the Solomon Islands is nearest to the present record in the Tanga Group. The largest specimen, ANU 60644 from the Tanga Group, measures 70 x 60 x 39 mm, considerably smaller than the largest known specimen, from Hawaii, measuring 130 x 108 x 74 mm (H.L. Clark 1946). The shape of the periproct of the Tanga Group and Cape Gazelle specimens, somewhat pointed above and below, differs from the rounded periproct evident in specimens figured by Mortensen (1951: Plate XXXIII, fig. 7) and Miskelly (2002). In this respect, the Bismarck Sea specimens closely resemble *Brissus (Allobrissus) agassizii* Döderlein 1885 (Mortensen 1951: Plate XXXIII, fig. 7). Gibbs et al. (1976) noted the similarity of a Pelican Island, Great Barrier Reef, specimen of *B. (B.) latecarinatus* with *B. (A.) agassizii*. The posterior end of this particular specimen, like that of *B. (A.) agassizii*, is vertically truncated, with the posterior interambulacrum being only slightly carinate aborally (and not prolonged backwards to overhang the periproct and conceal it from dorsal view).

Genus METALIA Gray 1855

Synonymy

Xanthobrissus Agassiz 1863, p. 28.

Prometalia Pomel 1883, p. 34.

Eobrissus Bell 1904, p. 236.

Metaliopsis Fourtau 1913, p. 68.

Type species

Spatangus sternalis Lamarck 1816, p. 326, by original designation.

Metalia spatagus (Linnaeus 1758)

Synonymy

Echinus spatagus Linnaeus 1758, p. 665.

Metalia spatagus (Linnaeus 1758): H.L. Clark 1925, p. 216; H.L. Clark 1932, p. 219; H.L. Clark 1946, p. 372; Mortensen 1951, p. 540; A.M. Clark and Rowe 1971, p. 166; Gibbs et al. 1976, p. 136; Rowe and Gates 1995, p. 190.

Mortensen (1951: 540) lists additional synonymies.

Material and locality

Two naked tests, ANU 60646-7, from Nosnos village, Boang Island, Tanga Group, New Ireland Province, PNG.

Remarks

Metalia spatagus (Linnaeus 1758) is widely distributed through the Indo-Pacific (Mortensen 1951; A.M. Clark and Rowe 1971). H.L. Clark (1932) provided the first record of this species from Australasian waters (Low Isles, Great Barrier Reef), recording the largest known specimen, measuring 110 x 93 x 52 mm. By comparison, the largest Tanga specimen measures 54 x 40 x 29 mm. Miskelly (2002) records the species from the Solomon Islands.

FOSSIL AND LIVING ECHINODERMS FROM PAPUA NEW GUINEA

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REFERENCES

- Agassiz, A. (1863). List of the echinoderms sent to different institutions in exchange for other specimens, with annotations. *Bulletin of the Museum Comparative Zoology, Harvard* **1**(2) 17-28.
- Agassiz, A. (1879). Preliminary report on the Echini of the exploring expedition of H.M.S. Challenger. *Proceedings of the American Academy of Arts and Sciences* **14** 190-212.
- Agassiz, A. (1881). *Report on the scientific results of the voyage of H.M.S. Challenger during the years 1873-76: Zoology - vol. 3, pt. 9, Report on the Echinoidea*. 321pp. (H.M. Stationery Office: London).
- Bell, F.J. (1899). Report on the Echinoderms (other than Holothurians) collected by Dr. Willey. In 'Zoological results based on material from New Britain, New Guinea, Loyalty Islands and elsewhere, collected during the years 1895 1896 and 1897' (Ed. A. Willey) Part II 133-140. (Cambridge University Press: Cambridge).
- Bouillon, J. and Jangoux, M. (1984). Note on the relationship between the parasitic mollusk *Thyca crystallina* (Gastropoda, Prosobranchia) and the starfish *Linckia laevigata* (Echinodermata) on Laing Island reef (Papua New Guinea). *Annales de la Societe Royale Zoologique de Belgique* **114**, 249-256.
- Britayev, T.A., Doignon, G. and Eeckhaut, I. (1999). Symbiotic polychaetes from Papua New Guinea associated with descriptions of three new species. *Cahiers de Biologie Marine* **40**, 359-374.
- Chapman, F. and Cudmore, F.A. (1934). The Cainozoic Cidaridae of Australia. *Memoirs of the National Museum Melbourne* **8** 126-149.
- Clark, A.H. (1954). Records of Indo-Pacific echinoderms. *Pacific Science* **8**, 243-263.
- Clark, A.M. (1968). 'Starfishes and their relations'. (British Museum (Natural History): London). 120pp.
- Clark, A.M. and Rowe, F.W.E. (1971). Monograph of shallow-water Indo-West Pacific echinoderms. *British Museum (Natural History) Publication* **690**, 238pp.
- Clark, H.L. (1908). Some Japanese and East Indian echinoderms. *Bulletin of the Museum of Comparative Zoology, Harvard* **51** (11), 279-311.
- Clark, H.L. (1925). A catalogue of the recent Sea-Urchins (Echinoidea) in the collection of the British Museum (Natural History). (British Museum (Natural History): London). 250pp.
- Clark, H.L. (1932). Echinodermata (other than Asteroidea). *Scientific Reports of the Great Barrier Reef Expedition* **4** 197-239.
- Clark, H.L. (1946). The Echinoderm Fauna of Australia: Its Composition and Its Origin. *Carnegie Institution of Washington, Publication* **566**, 567pp.
- Corbett, G., First, D.M. and Hayward, S.B. (1991). The Maragorik Prospect, east New Britain, Papua New Guinea. In 'Proceedings of the PNG Geology, Exploration and Mining Conference 1991, Rabaul' (Ed. R. Rogerson) pp. 112-116. (The Australasian Institute of Mining and Metallurgy: Melbourne).
- De Ridder, C. (1986). Les échinides. In 'Guide des étoiles de mer, oursins et autres échinodermes du lagon de Nouvelle-Calédonie' (Eds A. Guille, P. Laboute and J.-L. Menou) pp. 22-53. (Institut Français de Recherche Scientifique pour le Développement en Coopération. Collection Faune Tropicale **25**).
- Durham, J.W. (1966). Phylogeny and evolution. In 'Treatise on Invertebrate Paleontology, Part U, Echinodermata 3' (Ed. R.C. Moore) pp. U266-U269. (Geological Society of America and University of Kansas Press: Lawrence).
- Eeckhaut, I., Deheyn, D. and Jangoux, M. (1996). Study on the symbiotic fauna of crinoids collected in Hansa Bay (Bismarck Sea, Papua New Guinea). *Ninth International Echinoderm Conference, San Francisco, August 1996*. pp. 516. (A.A. Balkema, Rotterdam).
- Endean, R. (1957). The biogeography of Queensland's shallow-water echinoderm fauna (excluding Crinoidea), with a rearrangement of the faunistic provinces of tropical Australia. *Australian Journal of Marine and Freshwater Research* **8**, 233-273.
- Fell, H.B. (1966). Cidaroids. In 'Treatise on Invertebrate Paleontology, Part U, Echinodermata 3' (Ed. R.C. Moore) pp. U312-U340. (Geological Society of America and University of Kansas Press: Lawrence).

- Fell, H.B. and Pawson, D.L. (1966). Echinacea. In 'Treatise on Invertebrate Paleontology, Part U, Echinodermata 3' (Ed. R.C. Moore) pp. U367-U440. (Geological Society of America and University of Kansas Press: Lawrence).
- Fischer, A.G. (1966). Spatangoids. In 'Treatise on Invertebrate Paleontology, Part U, Echinodermata 3' (Ed. R.C. Moore) pp. U543-U628. (Geological Society of America and University of Kansas Press: Lawrence).
- Fisher, W.K. (1919). Starfishes of the Philippine Seas and adjacent waters. *United States National Museum Bulletin* **100**(3), 711pp.
- Francis, G. (1985). Stratigraphy of Manus Island, western New Ireland Basin, Papua New Guinea. *Geological Survey of Papua New Guinea Report* **85/10**, 40 pp.
- Gibbs, P.E., Clark, A.M. and Clark, C.M. (1976). Echinoderms from the northern region of the Great Barrier Reef, Australia. *Bulletin of the British Museum (Natural History) (Zoology)* **30**(4) 103-144.
- Koehler, R. (1910). An account of the shallow-water asteroidea. *Echinoderma of the Indian Museum*. (Trustees of the Indian Museum: Calcutta). 192pp.
- Lindley, I.D. (1988). Early Cainozoic stratigraphy and structure of the Gazelle Peninsula, east New Britain: An example of extensional tectonics in the New Britain arc-trench complex. *Australian Journal of Earth Sciences* **35**, 231-244.
- Lindley, I.D. (2003a). Echinoids of the Kairuku Formation (Lower Pliocene), Yule Island, Papua New Guinea: Clypeasteroidea. *Proceedings of the Linnean Society of New South Wales* **124** 125-136.
- Lindley, I.D. (2003b). Echinoids of the Kairuku Formation (Lower Pliocene), Yule Island, Papua New Guinea: Regularia. *Proceedings of the Linnean Society of New South Wales* **124** 137-151.
- Loriol, P. de. (1891). Notes pour servir à l'étude des Echinoderms. III. *Mém. Soc. Phys. Hist. nat. Genève* vol. suppl. **8** 1-31.
- Martin, K. (1918). Unsere palaeozoologische Kentiss von Java. *Beilage-Band zu Sammlungen des Geologischen Reichsmuseums in Leiden*. 118pp.
- McNamara, K.J. and Kendrick, G.W. (1994). Cenozoic molluscs and echinoids of Barrow Island, Western Australia. *Records of the Western Australian Museum*, Supplement No. **51**, 50pp.
- McNamara, K.J. and Philip, G.M. (1980a). Australian Tertiary schizasterid echinoids. *Alcheringa* **4**, 47-65.
- McNamara, K.J. and Philip, G.M. (1980b). Living Australian schizasterid echinoids. *Proceedings of the Linnean Society of New South Wales* **104** 127-146.
- Messing, C.G. (1994). Comatulid crinoids (Echinodermata) of Madang, Papua New Guinea and environs: diversity and ecology. In 'Echinoderms through time' (Eds D.B. Guille, A. Féral, J.-P. and M. Roux) pp. 237-243. (A.A. Balkema: Rotterdam).
- Miskelly, A. (2002). 'Sea urchins of Australia and the Indo-Pacific'. (Capricornica Publications: Sydney). 179 pp.
- Mortensen, T. (1928a). A Monograph of the Echinoidea I, Cidaroida. (C.A. Reitzel, Copenhagen). 551 pp.
- Mortensen, T. (1928b). Papers from Dr. Th. Mortensen's Pacific expedition 1914-16. New Cidaridae. *Videnskabelige Meddelelser fra Dansk Naturhistorisk Forening i København* **85**, 65-74.
- Mortensen, T. (1943a). A Monograph of the Echinoidea III.2 Camarodonta I: Orthopsidae, Glyphocyphidae, Temnopleuridae and Toxopneustidae. (C.A. Reitzel, Copenhagen). 553 pp.
- Mortensen, T. (1943b). A Monograph of the Echinoidea III.3 Camarodonta II: Echinidae, Strongylocentrotidae, Parasalenidae, Echinometridae. (C.A. Reitzel, Copenhagen). 446 pp.
- Mortensen, T. (1948a). A Monograph of the Echinoidea IV.1 Holectypoida, Cassiduloida. (C.A. Reitzel, Copenhagen). 371 pp.
- Mortensen, T. (1948b). A Monograph of the Echinoidea IV.2 Clypeasteroidea: Clypeasteridae, Arachnoidae, Fibulariidae, Laganidae and Scutellidae. (C.A. Reitzel, Copenhagen). 471 pp.
- Mortensen, T. (1951). A Monograph of the Echinoidea V.2 Spatangoida II: Amphisternata II, Spatangidae, Loveniidae, Pericosmidae, Schizasteridae, Brissidae. (C.A. Reitzel, Copenhagen). 593 pp.
- Müller, J. and Troschel, F.H. (1842). 'System der Asteriden'. (Papier, Druck and Verlag: Braunschweig). 134 pp.
- Negretti, B., Philippe, M., Soudet, H.J., Thomassin, B.A. and Oggiano, G. (1990). *Echinometra miocenica* Loriol, echinide Miocène, synonyme d'*Echinometra mathaei* (Blainville), actuel: Biogéographie et paléocéologie. *Geobios* **23**, 445-456.
- Philip, G.M. (1965). The Tertiary echinoids of south-eastern Australia III Stirodonta, Aulodonta, and Camarodonta (1). *Proceedings of the Royal Society of Victoria* **78**(2): 181-196.
- Read, J.R.L. (1965). Preliminary geological investigation of the lower Warangoi hydro-electric scheme. New Britain August-November 1964. *Bureau of Mineral Resources, Geology and Geophysics, Record* **1982/15**.
- Rowe, F.W.E. and Gates, J. (1995). Echinodermata. In 'Zoological Catalogue of Australia', Vol. 33. 510 pp. (CSIRO Australia: Melbourne).
- Sladen, W.P. (1889). *Report on the scientific results of the voyage of H.M.S. Challenger during the years 1873-76: Zoology - vol. 30, Report on the*

FOSSIL AND LIVING ECHINODERMS FROM PAPUA NEW GUINEA

- Asteroidea*. 893pp. (H.M. Stationery Office: London).
- Spencer, W.K. and Wright, C.W. (1966). Asterozoans. In 'Treatise on Invertebrate Paleontology, Part U, Echinodermata 3' (Ed. R.C. Moore) pp. U4-107. (Geological Society of America and University of Kansas Press: Lawrence).
- Sluiter, C.P. (1895). Die Asteriden Sammlung des Museums zu Amsterdam. Die Echiniden Sammlung des Museums zu Amsterdam. *Bijdragen tot de Dierkunde* **17**, 49-64, 65-74.
- Struder, T. (1876). Über Echinodermen aus dem antarktischen Meere und zwei neue Seeigel von den Papua-Inseln gesammelt auf der Reise S.M.S. 'Gazelle' um die Erde. *Monatsberichte der Königlich Preussischen Akademie der Wissenschaften zu Berlin* **1876**, 452-465.
- Struder, T. (1880). Übersicht über die während der Reise S.M.S. Corvette 'Gazelle' um die Erde 1874-76 gesammelten Echinoiden. *Monatsberichte der Königlich Preussischen Akademie der Wissenschaften zu Berlin* **1880**, 861-885.
- Wagner, C.D. and Durham, J.W. (1966). Holoctypoids. In 'Treatise on Invertebrate Paleontology, Part U, Echinodermata 3' (Ed. R.C. Moore) pp. U440-450. (Geological Society of America and University of Kansas Press: Lawrence).
- Wallace, D.A., Johnson, R.W., Chappell, B.W., Arculus, R.J., Perfit, M.R. and Crick, I.H. (1983). Cainozoic volcanism of the Tabar, Lihir, Tanga and Feni Islands, Papua New Guinea: Geology, whole-rock analyses, and rock-forming mineral compositions. *Bureau of Mineral Resources, Geology and Geophysics, Report* **243**.
- Willey, A. (1902). Zoological results based on material from New Britain, New Guinea, Loyalty Islands and elsewhere, collected during the years 1895 1896 and 1897. Pt. 2. (Cambridge University Press: Cambridge). 253pp.
- Woods, H. (1958). 'Palaeontology Invertebrate'. (Cambridge University Press; Cambridge). 477pp.

Table 1. Reported starfishes from the Bismarck Archipelago, Papua New Guinea.

ASTERIINAE

Tarsaster stoichodes Sladen 1889: Fisher 1919, p. 491: north of the Admiralty Group (150 fathoms).

ASTERINIDAE

Asterina cephus (Müller and Troschel 1842): A.H. Clark 1954, p. 258: Seleo Island, Aitape district.

Patriella exigua (Lamarck 1816): A.H. Clark 1954, p. 258: Admiralty Group; Seleo Island, Aitape district.

ASTEROPSEIDAE

Asteropsis carinifera (Lamarck 1816): A.H. Clark 1954, p. 258: Seleo Island, Aitape district.

ASTROPECTINIIDAE

Astropecten monacanthus Sladen 1883: Bell 1899, p. 136: New Britain.

Astropecten polyacanthus Müller and Troschel 1842: Fisher 1919, p. 64: Admiralty Group.

ECHINASTERIDAE

Echinaster luzonicus (Gray 1840): Rowe and Gates 1995, p. 59. (= *Echinaster eridanella* Müller and Troschel 1842, p. 24; Bell 1899, p. 138): New Ireland; New Britain.

LUIDIIDAE

**Luida aspera* Sladen 1889: Fisher 1919, p. 171: north of Admiralty Group (150 fathoms).

OPHIDIASTERIDAE

Linckia laevigata (Linnaeus 1758): Bouillon and Jangoux 1984, p. 249: Laing Island reef, Hansa Bay.

Nardoa novaecaledoniae (Perrier 1875): Rowe and Gates 1995, p. 88. (= *Nardoa mollis* de Loriol, 1891, H.L. Clark 1946, p. 115; A.H. Clark 1954, p. 255): New Britain; Seleo Island, Aitape district.

Nardoa tuberculata Gray 1840: Rowe and Gates 1995, p. 88. (= *Nardoa finschi* de Loriol 1891; *Nardoa pauciforis* von Martens 1866, H.L. Clark 1946, p. 115): New Britain.

Ophidiaster granifer Lütken 1871: A.H. Clark 1954, p. 256: Seleo Island, Aitape district.

OREASTERIDAE

+*Anthenea sidneyensis* Döderlein 1915: Rowe and Gates 1995, p. 98: Manus Island (Admiralty Group).

Calcita novaeguineae Müller and Troschel 1842: A.H. Clark 1954, p. 254: Seleo Island, Aitape district.

Pentaster obtusatus (Bory de St. Vincent 1827). [= *Pentaceros obtusatus* (Bory de St. Vincent 1827) Bell 1899, p. 136]: Blanche Bay, New Britain.

Protoreaster lincki (de Blainville 1830): *Oreaster lincki* (= *Pentaceros lincki*, Bell 1899, p. 136): Blanche Bay, New Britain.

Protoreaster nodosus (Linnaeus 1758): H.L. Clark 1946, p. 106; A.H. Clark 1954, p. 254. (= *Pentaceros nodosus*, Bell 1899: p. 136; *Oreaster nodosus* H.L. Clark 1908): Blanche Bay, New Britain; Seleo Island, Aitape district.

PTERASTERIDAE

Hymenaster pullatus Sladen 1889: Fisher 1919, p. 467: southwest of the Admiralty Group (1,070 fathoms).

NOTES

+ the writer follows Spencer and Wright (1966) and Rowe and Gates (1995) in placing *Anthenea* in Family Oreasteridae. H.L. Clark (1946) and A.M. Clark and Rowe (1971) placed the taxon in Family Goniasteridae.

* Denotes type locality in Bismarck Archipelago.

Table 2. Reported shallow and deep-water sea-urchins from the Bismarck Archipelago, Papua New Guinea.

ARACHNOIDIDAE

Arachnoides placenta (Linnaeus 1758): Bell 1899, p. 136; H.L. Clark 1925, p. 154: New Britain.

ARBACIIDAE

**Pygmaeocidaris prionigera* (A. Agassiz 1879): A. Agassiz 1881, pl. XXXIV, figs 14 and 15; H.L. Clark 1925, p. 73 (= *Podocidaris prionigera* A. Agassiz 1879, p. 199): between New Guinea and Admiralty Group (1,070 fathoms).

**Coelopleurus elegans* (Bell 1899): H.L. Clark 1925, p. 73. (= *Salmacis elegans* Bell 1899, p. 135): New Britain.

CIDARIDAE

Eucidaris metularia (Lamarck 1816): H.L. Clark 1925, p. 20. (= *Cidaris metularia* de Blainville, 1830, Bell 1899, p. 134): New Britain.

Prionocidaris baculosa var. *annulifera* (Lamarck): Mortensen 1928a, p. 437, 446. (= *Schleinitzia crenularis* Struder 1876, p. 463; 1880, p. 865): west New Guinea.

Stylocidaris reini (Döderlein): H.L. Clark 1925, p. 24; Mortensen 1928a, p. 342, 347, 474 (= *Phyllacanthus annulifera* Bell 1899, p. 134): New Britain; Milne Bay.

DIADEMATIDAE

Echinothrix calamaris (Pallas 1774): A.H. Clark 1954, p. 250: Bougainville Island.

**Micropyga nigra* H.L. Clark 1925: A. Agassiz 1879, p. 200; H.L. Clark 1925, p. 47. (= *Astropyga elastica* Struder, Bell 1899, p. 135): New Britain.

Micropyga tuberculata A. Agassiz 1879, p. 200: A. Agassiz 1881, pl. VII; H.L. Clark 1925, p. 48: Blanche Bay, New Britain.

ECHINOMETRIDAE

Echinometra mathaei (de Blainville 1825): A.H. Clark 1954, p. 251: Bougainville Island; Seleo Island, Aitape district; Normanby Island. (= *Echinometra lucunter* Bell 1899, p. 136).

ECHINOTHURIIDAE

Araeosoma gracile (A. Agassiz 1881): A. Agassiz 1881, p. 89; H.L. Clark 1925, p. 61: Admiralty Group (150 fathoms).

LAGANIDAE

Laganum decagonale (de Blainville 1827): A. Agassiz 1881; H.L. Clark 1925, p. 156; Mortensen 1948b, p. 332, 336; Lindley 2003a, p. 133: near Admiralty Group (150 fathoms).

Laganum depressum var. *tonganense* (Quoy and Gaimard): Mortensen 1948b, p. 324: Admiralty Group.

Laganum laganum (Leske): Mortensen (1948b), p. 312: Bismarck Archipelago.

SPATANGIDAE

Maretia ovata (Leske 1778): A. Agassiz 1881; H.L. Clark 1925, p. 226: Admiralty Group.

TEMNOPLEURIDAE

Prionechinus agassizii Wood-Mason and Alcock 1891: H.L. Clark 1925, p. 78. (= *Echinus elegans*, A. Agassiz 1881): near Admiralty Group.

**Prionechinus sagittiger* A. Agassiz 1879, p. 202: A. Agassiz 1881, pl. IVa, figs 11-14; H.L. Clark 1925, p. 79: between New Guinea and Admiralty Group (1,070 fathoms).

Temnopleurus sp., Bell 1899, p. 135: New Britain.

Temnopleurus reevesii (Gray 1855): A. Agassiz 1881; H.L. Clark 1925, p. 81: near Admiralty Group (150 fathoms).

Temnotrema scillae (Mazetti 1894): Mortensen 1904, p. 86; H.L. Clark 1925, p. 91 (= *Pleurechinus reticulatus* in H.L. Clark 1925, p. 91): New Britain.

TOXOPNEUSTIDAE

Tripneustes gratilla (Linnaeus 1758): A.H. Clark 1954, p. 250: Bougainville Island; Seleo Island, Aitape district.

INVALID RECORDS

Astriclypeus manni Verrill, Sluiter 1895, p. 73, New Ireland; Mortensen 1948b, p. 416, 418.

Colobocentrotus mertensi Brandt 1835, Sluiter 1895, p. 69, New Ireland; Mortensen 1943b, p. 433.

Mellita longifissa Michelin 1858, Sluiter 1895, p. 73, New Ireland; Mortensen 1948b, p. 427, 428.

Taxonomic reason: Erroneous labelling (Mortensen 1948b, p. 418; Mortensen 1943b, p. 433; Mortensen 1948b, p. 428, respectively).

NOTES

* Denotes type localities in Bismarck Archipelago